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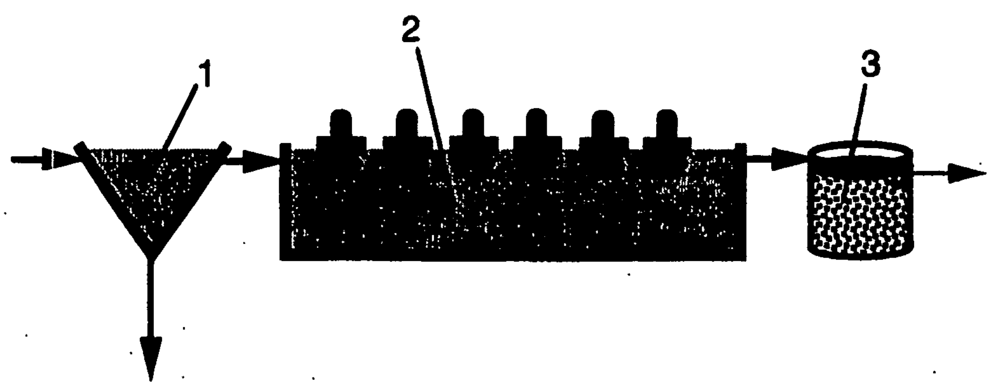

(57) Abstract

The invention relates to a method of improving the purification result in treating wastewater in biological aerated ponds by introducing after the aerated pond (2) and ahead of a following after-sedimentation (4), if any, a biofilm process (3) having a carrier material for microbial growth which is kept completely or partly in suspension and movement by blowing air into the process.

Method of cleaning waste water.

The invention relates to a method in improving the purification of wastewater in biological aerated ponds.

In biological wastewater purification the wastewater is passed through some type of reactor, tank or basin wherein micro-organisms are utilized for converting impurities existing in the water to harmless end products such as carbon dioxide and water. The purification i.a. can be performed under supply of air (aerobically) or without supply of air (anaerobically). In all biological purification processes the degraded impurities are converted into microbial biomass, a biosludge, which must be separated from the water and removed from the process, dewatered, and cleared off in some way usually by deposition or combustion. Handling of the sludge in connection with biological purification is connected with large operating costs, and it is therefore desired to have a sludge production as low as possible in the biological process.

A very simple form of biological purification process is the so called aerated pond, which is common i.a. in the forest industry. When wastewater is purified in an aerated pond or basin the wastewater is simply passed through the pond or basin wherein air is supplied by means of some type of aerating system. The active micro-organisms are not retained in the process and, therefore, the content of active micro-organisms usually is low in an aerated pond. In order to provide breakdown of the impurities in the wastewater a long dwelling time therefore is required for the wastewater in the aerated pond, often between two and ten days. At large wastewater flows this means that the process volume will be very large, often several hundred thousand cubic meters. Notwithstanding the long dwelling time of the wastewater in most aerated ponds the purification results are often unsatisfactory. The breakdown of

the organic impurities is often incomplete, and this is true particularly concerning many toxic impurities as well as impurities difficult to break down, which is of great importance with regard to the discharge. Moreover, the microbiological biomass produced in an aerated pond usually is very difficult to separate. In most cases the treatment in an aerated pond is followed by a separation step, usually in a sedimentation basin wherein the produced biomass shall be separated from the wastewater and removed as a surplus sludge. If this separation does not function it leads to large discharges of suspended material in the form of biomass which contains high contents of organic substance as well as considerable amounts of nutrient salts. This is a very common problem in connection with wastewater purification in aerated ponds. The advantage of the aerated pond is that it is very simple to operate and that the need of attendance and control is very small.

In order to obtain a more extensive breakdown of the organic impurities biological purification processes are often used wherein the active micro-organisms are retained in the process in order to maintain a high content of active biomass. There are two main principles for the performance of the retention. Either the biomass is allowed to grow in suspended form in the process and then is separated from the water in a separation step after the reactor and returned to the reactor (e.g. the activated sludge process), or the biomass is retained by the micro-organisms being allowed to grow as a biofilm on some type of carrier material included in the process (biofilm processes). In activated sludge processes as well as in biofilm processes there is usually obtained a considerable better purification result than in aerated ponds. The most extensive breakdown is obtained in activated sludge processes at low load, and a common method of improving the purification efficiency in existing aerated ponds is to

rebuild this ponds for activated sludge processes. This often requires extensive rebuilding of the pond and building of a new after-sedimentation, which involves great investment costs. The process also has the drawback that it requires considerably more attendance and control than the aerated pond. For hot wastewaters such as many wastewaters from the forest industry, it is also required that incoming water for the process is cooled down to a temperature below 40°C in order to avoid operational disturbances. For many industrial wastewaters it is also required that extra nutrient salts are added to the water before the treatment in a activated sludge process. A common problem in an activated sludge processes under low load is moreover that there arises sludge separation problems such as so-called sludge swelling, which may provide reduced purification results and difficulties in dewatering the surplus sludge which is removed from the process. The rebuilding also results in a considerable increase of the amount of surplus sludge that must be taken care of.

Biofilm processes usually are operated as processes under higher load which do not reach a purification degree which is as high as that of an activated sludge process at low load. Often biofilm processes are utilized as pre-treatment before a following activated sludge process but biofilm processes are also operated as the only biological purification sometimes in combination with a following chemical precipitation. A biofilm process is considerably simpler to operate than an activated sludge process and the need of attendance is low. However, as in the activated sludge process cooling of hot wastewater is required before treatment and addition of extra nutrient salts in the treatment of many industrial wastewaters which usually is not required for treatment in aerated ponds. It has already been shown that the purification results in aerated ponds can be improved by converting the ponds to a biofilm

process, which means that a carrier material is introduced directly in the aerated pond (SE-A-9501744-8). It has also been proposed to introduce in ponds which are not aerated a device which contains carrier material and through which the water is circulated (JP-A1-51193). Compared with rebuilding of an aerated pond for the activated sludge process these solutions have the advantage that the simple operation and the low demand of attendance will be maintained and that the risk of sludge swelling will be avoided. The drawback is, however, that there is a risk of the carrier material being overgrown and biosludge which comes off the carrier material forming sludge depositions on the bottom of the pond.

It has also already been proposed (FR-A1-2 358 364) to locate a biofilm process before an aerated pond. However, this alternative has been found to have several great drawbacks as compared with other solutions for improving the purification in aerated ponds. The process combination does not provide a purification which is as far-reaching as that achieved by rebuilding for activated sludge process, and for hot waters cooling is required in order that the biofilm process will operate satisfactorily. Moreover, large amounts of sludge are produced in the biofilm process, which either must be separated before the aerated pond, dewatered, and cleared off or, if it is allowed to pass into the aerated pond, causes a risk of formation of large sludge deposits on the bottom. The high sludge production also means that large amounts of nutrient salts must be supplied to the biofilm process. This leads to an increase of the nutrient salt discharge after the aerated pond instead of a reduction thereof when this process combination is used.

A new type of biofilm process which has found large application during recent years is the so called biofilm process with suspended carrier material (EP-A-0 575 314,

WO-A-95/25072). In this process carrier material in the form of filler bodies of plastics is used said bodies being kept suspended and in movement in the process by air being supplied at the bottom of the reactor tank. For purification of industrial wastewaters the process above all has found application as a pre-treatment at high load before a following treatment in activated sludge process or as the only biological purification at a slightly lower load and in combination with chemical precipitation.

The method proposed according to the present invention for improving purification of wastewater in biological aerated ponds has obtained the characterizing features of claim 1 and has been found to provide great advantages as compared with the conventional method of improving the purification. It has been found that by the combination of the two processes - the treatment in the aerated pond and the biofilm process - there is obtained a result which is substantially better than the sum of the effects obtained by the individual processes. Moreover, the invention comprises a further method of supplementing said process combination in order to reduce the discharge of suspended material, nitrogen and phosphorous.

By the invention there is obtained a breakdown of the organic impurities in the wastewater which is as good as that obtained by rebuilding for an activated sludge process but with great operational advantages. The process requires no rebuilding of the pond, only the introduction of a very compact process after the pond. Moreover, very small attendance, control, and instrumentation is required. No cooling of the incoming wastewater is required, and the sludge production will be considerably lower than in an activated sludge process. Compared with solutions already proposed including application of carrier material directly in the aerated pond the invention provides a more controllable process and eliminates the risk of clogging of

the carrier material or collection of sludge in the pond. The invention also provides a considerably lower sludge production than an installation of carrier material in the pond. At a comparison in pilot scale between the invention and other alternatives for improving the purification results in an aerated pond there was obtained by the invention a sludge production of 0.04 kg sludge/kg reduced COD while an installation of carrier material directly in the pond gave a sludge production of 0.10 kg sludge/kg reduced COD, and rebuilding for an activated sludge process gave a sludge production of 0.14 kg sludge/kg reduced COD.

A comparison between the combination according to the invention and treatment of the wastewater in an aerated pond or biofilm process individually also showed that the combination according to the invention provides a considerably better result than the sum of the effects of the two processes individually. As will be seen from TABLE 1 below the reduction of the nutrient salts nitrogen and phosphorous and the acute toxicity was improved dramatically the sludge production and the discharge of suspended material at the same time being heavily reduced by treatment in the process combination according to the invention as compared with the two individual processes.

TABLE 1. Comparison between the purification result in an aerated pond, a biofilm process, and the combination of aerated pond and biofilm process according to the invention

	Aerated pond	Biofilm	Aerated pond + biofilm
Dwelling time (h)	70	2	70 + 2
COD-reduction (%)	30	35	70
Sludge production (kg/kg reduced COD)	0.29	0.32	0.04
Reduction of acute toxicity (%)	30	42	100
Reduction of phosphorous (%)	10	increases	70
Reduction of nitrogen (%)	increases	increases	60
Discharge of suspended material (mg/l)	90	50	25

A comparison with other types of biofilm processes having stationary carrier material has shown that these are considerably less well suited to be utilized for the actual application. Thus, the treatment of outgoing water from an aerated pond in a biofilm process has been found to cause a very heavy biofilm growth with following clogging and impaired contact between the wastewater and the biomass in biofilm processes having stationary carrier material so that it has not been possible to achieve the desired effects by these processes. In the process having suspended carrier material the movement of such material in the water avoids overgrowing and secures a good contact between the wastewater and the biofilm all the time.

For some wastewaters the very low sludge production obtained in a process combination according to the invention has been found to cause problems in achieving high separation degrees of nutrient salts in the process. This is true particularly for wastewaters containing considerable amounts of nutrient salts in relation to the organic material in the wastewater. Nutrient salts can be separated from the wastewater primarily by said salts being

absorbed by the micro-organisms and being built into the biomass produced by the growth of the micro-organisms. By separating this biomass from the wastewater after the biological purification process the nutrient salts contained in the biomass will also be separated. If the growth of biomass in the process, the sludge production, is very low it may happen, however, that the absorption of nutrient salts will be so low that the discharge of said salts from the process will be higher than desired. If this is the case it has been found favourable to convey a partial flow of untreated wastewater past the aerated pond directly into the biofilm process. This has been found to give an increased sludge production in the biofilm process so that a larger portion of the nutrient salts in the wastewater will be taken up and bound by the sludge. The invention also relates to this method of improving the separation of nutrient salts.

In case the wastewater is spontaneously cooled to low temperatures in the aerated pond it may be advantageous to convey a partial flow of the warmer untreated wastewater past the aerated pond directly to the biofilm process in order that the temperature in said process will be kept at a more optimal level. To convey a partial flow of wastewater past the pond directly to the biofilm process has also been found to improve the possibility of separating the surplus sludge from the biofilm process.

The effect on the nutrient salt separation by conveying untreated wastewater past the aerated pond directly into the biofilm process was clearly demonstrated by pilot tests wherein a combination of aerated pond and biofilm process according to the invention, before a partial flow of untreated wastewater was conveyed past the aerated pond gave a separation of nitrogen and phosphorous of 10 and 25 %, respectively, while the separation after 20 % of the wastewater having been flown past the pond

directly to the biofilm process increased to 55 and 67 %, respectively.

For many wastewaters the nutrient salts separation will be good even if untreated wastewater is not conveyed to the biofilm process. In many cases no nutrient salt separation is aimed at, and in these cases it is relatively common that there is no separation step after the aerated pond the treated wastewater with biosludge existing therein being discharged directly to the recipient. For these cases the invention can provide a substantial reduction of the discharge of organic material and suspended substances by breakdown thereof in the biofilm process before discharge to the recipient.

In order to further improve the purification it has been found possible to locate an aerated tank after the biofilm process, biosludge being returned to said tank from a following separation step. This after-treatment is thus operated according to the active sludge principle but with a much shorter treatment period than that required by an activated sludge process without proceeding aerated pond and biofilm process. The function of the following activated sludge system is to further improve the separation of suspended material from the wastewater. Thus, it has been found possible to reduce in this manner the outgoing content of suspended material from about 25 mg/l to about 10 mg/l. This reduction of outgoing suspended material also improves the separation of nutrient salts from the wastewater. Moreover, some improvement of the breakdown of solved organic material can be achieved by introducing the actual after-treatment.

For the same reason as has been described above regarding the biofilm process it may in some cases be advantageous to convey a partial flow of untreated wastewater past the aerated pond and the biofilm process directly into the activated sludge system. This leads to an

increased sludge production in the activated sludge step and thus an increased absorption of nutrient salts. In order to increase the separation of nutrient salts untreated wastewater thus can be conveyed past the aerated pond to the biofilm process or to the activated sludge process, or to both processes.

An alternative to the location of an activated sludge process after the biofilm process in order to further improve the purification is to return sludge from a separation step following the biofilm process, directly to the biofilm process, i.e. to operate the process as a hybrid between a biofilm process and an activated sludge process. This gives principally the same result as the biofilm process in combination with a separate activated sludge process but requires slightly lower dwelling time in the biofilm process than if said latter process is operated with a following activated sludge process. In some cases there can also be obtained a slightly impaired separatability of the active sludge. Also for this embodiment of the invention it may be advantageous to convey a partial flow of untreated wastewater past the aerated pond directly to the biofilm process for the same reason as mentioned above.

In order to explain the invention in more detail embodiments are presented below reference being made to the accompanying drawings in which

FIG. 1 discloses an embodiment of the invention with a subsequent sedimentation step,

FIG. 2 discloses the same process combination as FIG. 1 but without a subsequent sedimentation step,

FIG. 3 discloses the same process combination as FIG. 1 but with a shunted partial flow of untreated wastewater,

FIG. 4 discloses a process combination with activated sludge process,

FIG. 5 discloses the same process combination as FIG. 4 but with a shunted partial flow of untreated wastewater,

FIG. 6 discloses the same process combination as FIG. 4 but with two shunted partial flows of untreated wastewater,

FIG. 7 discloses the same process combination as FIG. 1 but wherein sludge is returned from the subsequent sedimentation step to the biofilm process, and

FIG. 8 discloses the same process combination as FIG. 7 but with a shunted partial flow of untreated wastewater.

In the plant according to FIG. 1 the untreated wastewater is passed to a presedimentation means 1 and therefrom to a biological aerated pond 2. The wastewater is passed from the pond to a tank 3 with carrier material for growth of biofilm, which is kept completely or partly suspended and in movement by air being blown into the tank in order to undergo a biofilm process therein. From the tank 3 the treated wastewater is discharged via a subsequent sedimentation means 4.

The plant in FIG. 2 does not have the sedimentation means 4 but in other respects corresponds to the plant in FIG. 1.

Also FIG. 3 discloses a plant corresponding to that in FIG. 1 but in this case a partial flow 5 of wastewater is conveyed from the presedimentation means 1 past the aerated pond 2 directly to the tank 3 in order to undergo the biofilm process.

The plant in FIG. 4 also corresponds to that in FIG. 1 but is supplemented by an aerated reactor 6 for activated sludge process between the tank 3 and the subsequent sedimentation means 4 sludge from said latter means being returned to the reactor 6.

In a plant of the embodiment in FIG. 4 a partial flow 8 of wastewater according to FIG. 5 is conveyed from the pre-sedimentation means 1 directly to the reactor 6 for the activated sludge process in passing over the aerated pond 2 and the tank 3 for the biofilm process, while the plant according to FIG. 6 is a combination of the plants in FIGS. 3 and 5 the wastewater from the pre-sedimentation means 1 being conveyed directly to the tank 3 as well as the reactor 6 the aerated pond 2 being passed over.

The plant in FIG. 7 corresponds to that in FIG. 1 but in this case sludge 7 is returned from the subsequent sedimentation means 4 to the biofilm process 3.

In a plant of the embodiment in FIG. 7 a partial flow 8 of wastewater according to FIG. 8 is conveyed from the presedimentation means directly to the biofilm process.

CLAIMS

1. Method in improving the purification of wastewater in biological aerated ponds **characterized** in that the wastewater after treatment in the aerated pond (2) is passed to a biofilm process (3) wherein active micro-organisms grow on a carrier material which is kept completely or partly in suspension and movement by air being blown into the process.

2. Method according to claim 1 **characterized** in that the dwelling time of the wastewater in the biofilm process (3) is between 0.3 and 10 h, particularly between 0.5 and 5 h, preferably between 1 and 4 h.

3. Method according to claim 1 or 2 **characterized** in that a partial flow (5) of biological untreated wastewater is conveyed past the aerated pond (2) directly into the biofilm process (3).

4. Method according to claim 3 **characterized** in that the partial flow (5) of biological untreated wastewater conveyed past the aerated pond (2) directly into the biofilm process (3) comprises between 5 and 70 %, particularly between 10 and 50 %, preferably between 20 and 40 % of the total wastewater flow to the biofilm process.

5. Method according to any of claims 1 to 4 **characterized** in that the wastewater from the biofilm process (3) is supplied to an aerated reactor (6) having a following separation step (4) from which sludge is returned to the reactor.

6. Method according to claim 5 **characterized** in that the dwelling time of the wastewater in the aerated reactor (6) is between 0.5 and 10 h, particularly 0.7 and 7 h, preferably between 1 and 5 h.

7. Method according to claim 5 or 6 **characterized** in that a partial flow (8) of biological untreated wastewater is conveyed past the aerated pond (2) and the biofilm process (3) directly into the aerated reactor (6).

8. Method according to claim 7 **characterized** in that the partial flow (8) of biological untreated wastewater which is conveyed past the aerated pond (2) and the biofilm process (3) directly into the aerated reactor (6) comprises between 5 and 70 %, particularly between 10 and 50 %, preferably between 20 and 40 % of the total wastewater flow to the aerated reactor.

9. Method according to claim 5 or 6 **characterized** in that two partial flows (5, 8) of biological untreated wastewater are conveyed past the aerated pond (2) directly to the biofilm process (3) and the aerated reactor (6), respectively.

10. Method according to claim 9 **characterized** in that the two partial flows (5, 8) of biological untreated wastewater which are flown past the aerated pond (2) together comprise between 5 and 70 %, particularly between 10 and 50 %, preferably between 20 and 40 % of the total wastewater flow to the aerated reactor (6).

11. Method according to any of claims 1 to 4 **characterized** in that sludge is returned to the biofilm process (3) from a following separation step (4).

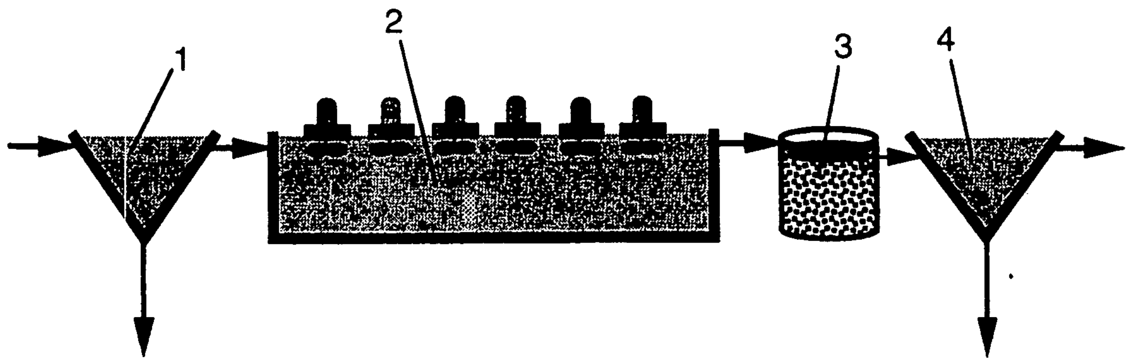

FIG 1

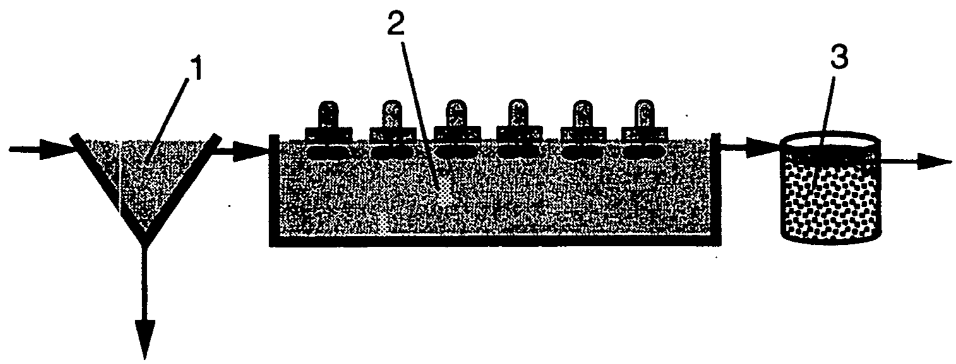

FIG 2

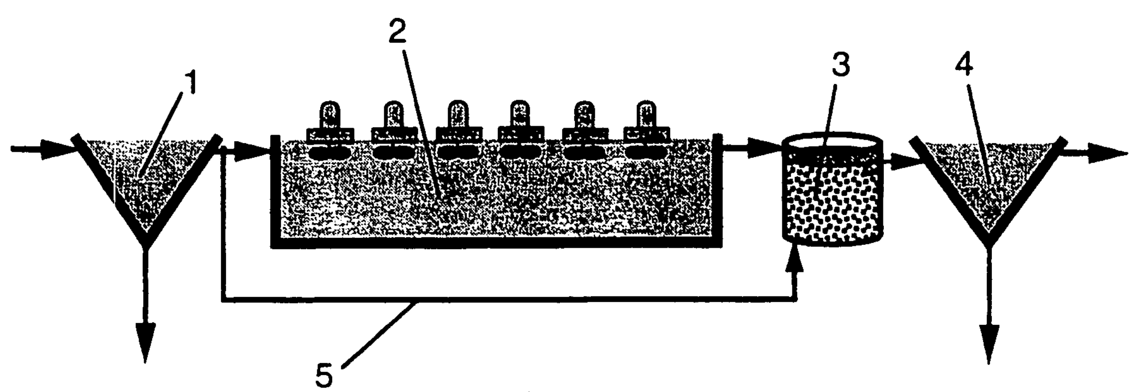

FIG 3

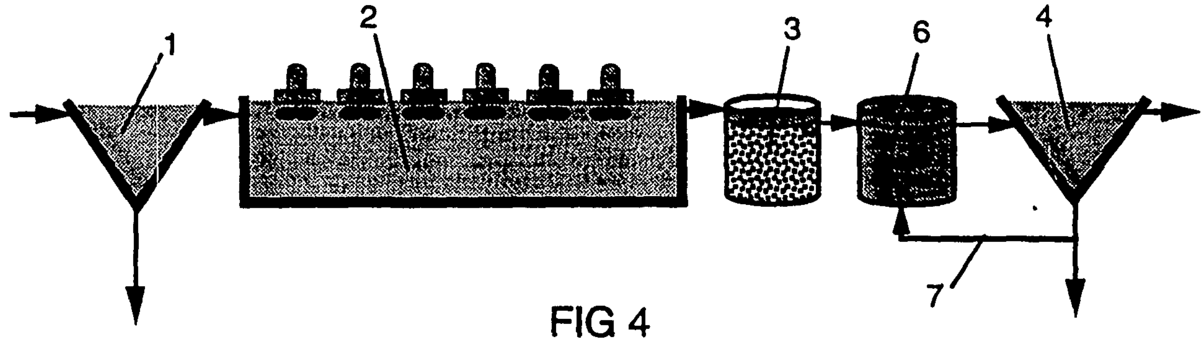

FIG 4

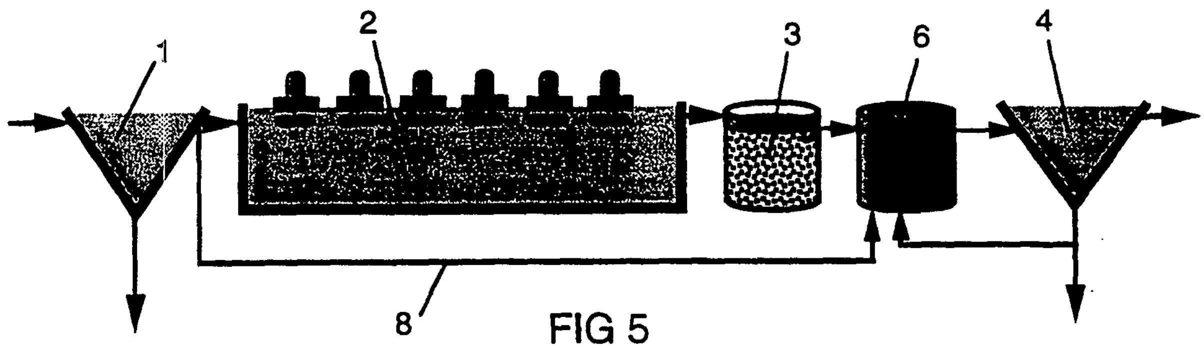

FIG 5

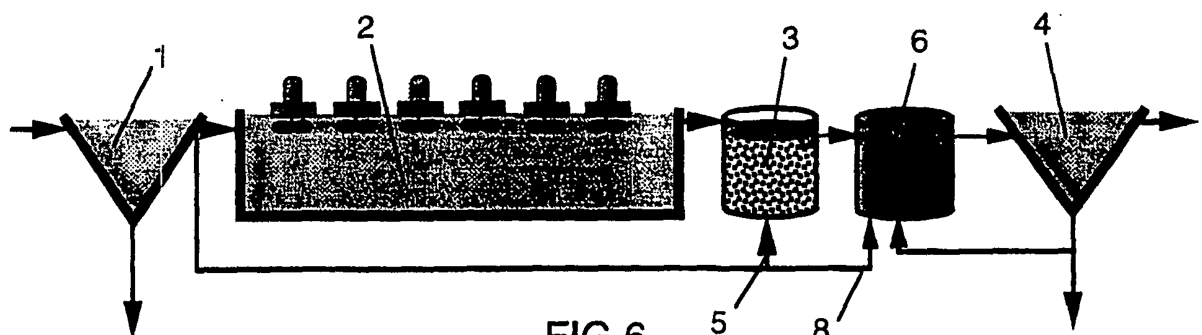

FIG 6

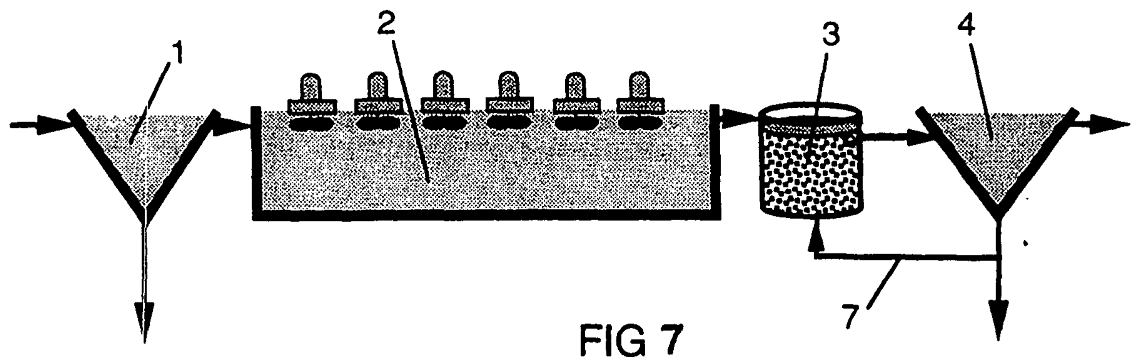

FIG 7

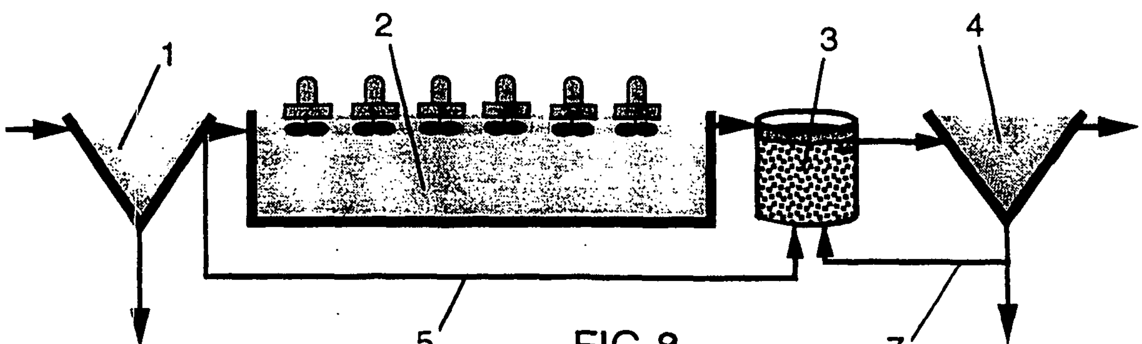

FIG 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00375

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C02F 3/02, C02F 3/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, Vol 13,No 241, C-604 abstract of JP 1-51193 A (ATAKA KOGYO K.K.), 27 February 1989 (27.02.89) --	1
A	FR 2358364 A (DEGREMONT), 10 February 1978 (10.02.78), claim 1 --	1
A	WO 9525072 A1 (ANOX AB), 21 Sept 1995 (21.09.95), figure 9, claim 1 -- --------	1

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
24 June 1998	26 -06- 1998
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INTERNATIONAL SEARCH REPORT
Information on patent family members

09/06/98

International application No.
PCT/SE 98/00375

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2358364 A	10/02/78	AR 217257 A	14/03/80
		BR 7703917 A	11/04/78
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